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A Dual-Ship Approach to the 21st Century Surface Combatant (SC21) Program

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The rapid decline of the defense budget since the fall of the Soviet Union has led to severely reduced procurement accounts for all the Military Services, and these declining budgets are likely to continue well into the next decade. For the Department of the Navy, with its many competing procurement demands, the declining budgets mean that (a) future shipbuilding must be scaled back, and (b) the question of quantity versus capability will become the paramount question as the Navy develops requirements for all new ships. In this paper, which was prepared prior to the start of the Cost and Operational Analysis of the next-generation surface combatant (SC21), I propose that one alternative that should be considered for the SC21 requirement is a set of two ships: a fully capable ship and a moderately capable ship, with the moderately capable design potentially having Coast Guard and foreign military sales application. For maximum standardization and affordability, the two ship types should be designed concurrently by one design team and introduced into the fleet at the same time in a mix consistent with fleet sizing requirements. To meet expected budgetary constraints, both ship types should be developed with firm design-to-cost constraints.

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Summary

The rapid decline of the defense budget since the fall of the Soviet Union has led to severely reduced procurement accounts for all the Military Services, and these declining budgets are likely to continue well into the next decade. For the Department of the Navy, with its many competing procurement demands, the declining budgets mean that (a) future shipbuilding must be scaled back, and (b) the question of quantity versus capability will become the paramount question as the Navy develops requirements for all new ships.

In this paper, which was prepared prior to the start of the Cost and Operational Effectiveness Analysis (COEA) of the next-generation surface combatant (SC21), I propose that *one alternative that should be considered for the next-generation surface combatant (SC21) requirement is a set of two ships: a fully capable ship and a moderately capable ship, with the moderately capable design potentially having Coast Guard and foreign military sales application. For maximum standardization and affordability, the two ship types should be designed concurrently by one design team and introduced into the fleet at the same time in a mix consistent with fleet sizing requirements.* To meet expected budgetary constraints, *both ship types should be developed with firm design-to-cost constraints.*

Introduction

> The DOD is in serious budgetary trouble. Externally, critics of the Defense Department are demanding that the defense budget be reduced by applying the "peace dividend" to non-defense areas. Further, pressures to hold down total Government spending make DOD a prime candidate for cuts...and the need to replace aging weapon systems... is becoming more critical every day. It is obvious that DOD must find ways not only to control cost overruns so that its planning will be more orderly, but also to reduce the *actual* costs of its weapon systems if we are to have viable forces within the foreseeable budget ceilings [1].

These statements sound familiar today, but the introductory paragraph just cited, which describes so clearly today's post-Cold War dilemma, was written in 1973 as a description of problems facing the nation in the post-Vietnam War era. Those budget problems brought into focus then, as now,

> a professional disagreement that was, and continues to be, one of the most divisive in the Navy. Reduced to its simplest terms, it is whether the Navy can better perform its mission with a large number of ships, many of which (but not all) would have to be rather small and austere, the fiscal situation being what it is, or with a small number of big, powerful, sophisticated ships [2].

As the Navy prepares to develop requirements for the next generation of surface combatants for the 21st century (SC21), the issue of quantity versus capability is as germane today as it was in the early 1970s. I believe that the Navy's solution of the 1970s—the introduction of a mix of ships, some of which are not fully capable for all missions—is even more appropriate today than it was then, because it will allow the Navy to meet future requirements for high- and low-end surface combatant missions while holding to strict budget constraints.

Quantity versus capability

For some, the answer to the question of numbers versus performance is obvious. Admiral Zumwalt, the father of the "high-low mix" concept in the 1970s, has been unequivocal about the need for a large number of ships:

> All anyone has to do is look at a map of the world and see the vast expanses of water that America's commitments to her friends and allies make it necessary for the United States to use freely to conclude that a large number of platforms is the critical need. They are needed to protect carriers and amphibious forces, to track down and destroy enemy submarines and aircraft, to escort troop and supply convoys, to patrol narrow or coastal waters. I would like to be able to present the argument of those who take the opposing view but, frankly, I do not think they have one [2].

In short, to meet mission requirements, the Navy must be able to acquire and operate a large number of ships within a limited budget, and therefore all of the ships cannot be costly ships that provide optimum performance. Of course, today's mission is different from that of the 1970s. Most of the submarine threat disappeared with the demise of the Soviet Union (although conventionally powered submarines in Iran and North Korea are still a concern), and the diminished need for convoys and the reduced number of carrier battle groups should enable us to get along with fewer combatants than were needed then. However, an examination of the new mission foreseen by the Navy [3] reveals that it is hardly a recipe for a small fleet. In fact, while quite properly citing the need to defend against high-end threats ("forward-deployed surface combatants with upper and lower tier theater ballistic missile defense capabilities will play an increasingly important role..."), and continuing to "support the national strategic objectives through our enduring contributions in strategic deterrence, sea control and maritime supremacy, and strategic sea lift," *Forward From The Sea* also recognizes the wide range of

missions against relatively unsophisticated threats that have become prevalent in the new world order. These missions include "operations in Somalia, the Caribbean (both Haiti and Cuba), and Bosnia, as well as our continuing contribution to enforcement of UN sanctions against Iraq." Thus, whether (a) escorting Kuwaiti tankers in the Arabian Gulf, (b) stopping and boarding commercial shipping destined for Iraq in the Arabian Gulf and the Red Sea, (c) intercepting Cuban and Haitian refugees in the Caribbean, or (d) "participating in a variety of naval exercises with UNITAS, NATO standing forces, and coalition partners around the Pacific Rim, the Norwegian Sea, the Arabian Gulf and the Mediterranean basin," the Navy's required activities support the contention that America's vital interests—and therefore the Navy's mission—are worldwide, and are dependent in large measure upon the *quantity* of platforms. Just as important, these examples provide strong support for a ship with less than optimum capability, not merely as a means to hold down cost, but because much of the Navy's mission is low threat and wastefully inappropriate for such superships as Aegis cruisers and destroyers.

Still another advantage to having a surface combatant tailored for low or moderate threats, is the potential for favorable impact on the nation's industrial base. Today, the U.S. Air Force sells new aircraft to our friends and allies, and the U.S. Army sells new tanks, artillery, and other armored equipment. But the U.S. Navy seldom sells new ships. The Army and Air Force are thus able to benefit from reduced unit cost of their items because of economies of scale, and their industrial base is strengthened by an expanded market. (In recent years, the Army has procured from U.S. sources more weapon systems for foreign military sales than it has for its own use.) The Navy has not shared these advantages because its primary products—ships—have become too large, costly, and complex to be affordable or releasable to other navies.[1] However, if the Navy were to build a moderately capable ship—a ship incorporating modern technology but at a reasonable cost (that is, a ship expressly designed for the low-to-moderate threat

1. The Navy, of course, has transferred many ships to friends and allies in recent years, but all have been older classes such as the FFG-1, FF-1040, and the FF-1052 classes, and all have been sold or leased at relatively low cost compared to new construction costs.

missions described earlier)—foreign military sales of the ship would probably follow.[2] For example, four of the FFG-7 class frigates, the last affordable combatants built for the U.S. Navy, were built in the United States for Australia in the early 1980s, and construction of that class continues today in Spain and Taiwan, using combat systems and machinery built in America. A repeat of this scenario for a new class of moderately capable U.S. ships would add jobs to our shipbuilding industrial base beyond those required for a Navy program, and help lower the average unit cost for the U.S. Navy ships.

Certainly there are limits below which a design, if made any smaller and cheaper, would cease to have military value. In writing on "quality, quantity, and the balanced fleet," Phillip Pugh [4] cites the Royal Navy's Flower class ships, which

> were too small for ocean work and, when diverted from their intended coastal duties, they were hard-pressed to operate effectively in the North Atlantic. Anything smaller would have been valueless, however many could have been constructed.

But of course, there is also risk in developing warships so expensive that only a few can be afforded, as was the case with the SSN 21.

Pugh concludes that

> Not even the richest nations can afford capital ships in greater numbers than the very minimum needed for the missions assigned to its fleet. Capital ships have the most demanding requirements in terms of unit cost. Hence, the minimum unit cost (for them to have military value in their roles) is high and approaches the limit set by the budget. At this extreme, unit costs can only increase as fast as the budget...At the other extreme lie the numerous warships

2. Note that "moderately capable" as discussed in this paper does not mean "low quality." Rather, this term refers to a combatant that is fully shock-hardened, but with probably less growth potential than a "fully capable" ship, and with a weapons and sensor suite tailored for missions involving lower-end threats or for supplementing fully capable ships in a higher threat environment.

which it is important to have in relatively large numbers but which can be of modest size and, hence, low unit cost.

Making the case for a balanced fleet of both fully capable and moderately capable ships, however, is not enough. We need to determine the best way to achieve this balance. As we have in the past, we should meet our requirements for fully capable ships through new construction or modernization of existing fully capable ships. But the means to acquire the moderately capable portion of the fleet is not as straightforward. Some have argued that there is no need to construct moderately capable ships; rather, we should plan for the remaining[3] ships of the fleet, now fully capable, to take on moderate missions once their combat systems can no longer meet the state-of-the-art high-end threats that will emerge in the next decade. If so, what are the limits of this strategy—do we contemplate aging Aegis cruisers in the role of drug interdiction and the interception of boat people? For how long?

We cannot continue to build only costly fully capable ships without eventually reducing the fleet to a small number of large ships, some very old and capable of only moderately demanding missions, and a few very new and capable of difficult and complex missions. The use of aging fully capable ships for moderate missions may be useful as a stopgap measure, but to pursue this course as a matter of policy would result in a smaller fleet mainly made up of ships that are old technologically and have low reliability and high manning requirements, and our combatant industrial base would practically disappear. It is apparent, then, that our fleet needs moderately capable ships for balance and affordability, and that we will have to build some of these ships rather than depend on older ships, that were once fully capable, to do the job.

But how can we be certain that, through the vicissitudes of the budget process, the moderately capable ship doesn't become the *only* new ship, thus placing the Navy in the unacceptable position of having a fleet that is only marginally capable of succeeding in a high-threat environment early in the next century? And what management

3. Those fully capable ships that are not modernized.

actions should we take to ensure that what starts out as a moderately priced ship, doesn't gradually escalate in "required" capability and cost so much that when it reaches the production stage, it is neither fish nor fowl—too costly to be built in large numbers as originally planned, yet incapable of meeting the high-end threats to be faced in the early decades of the 21st century?

How the process works now

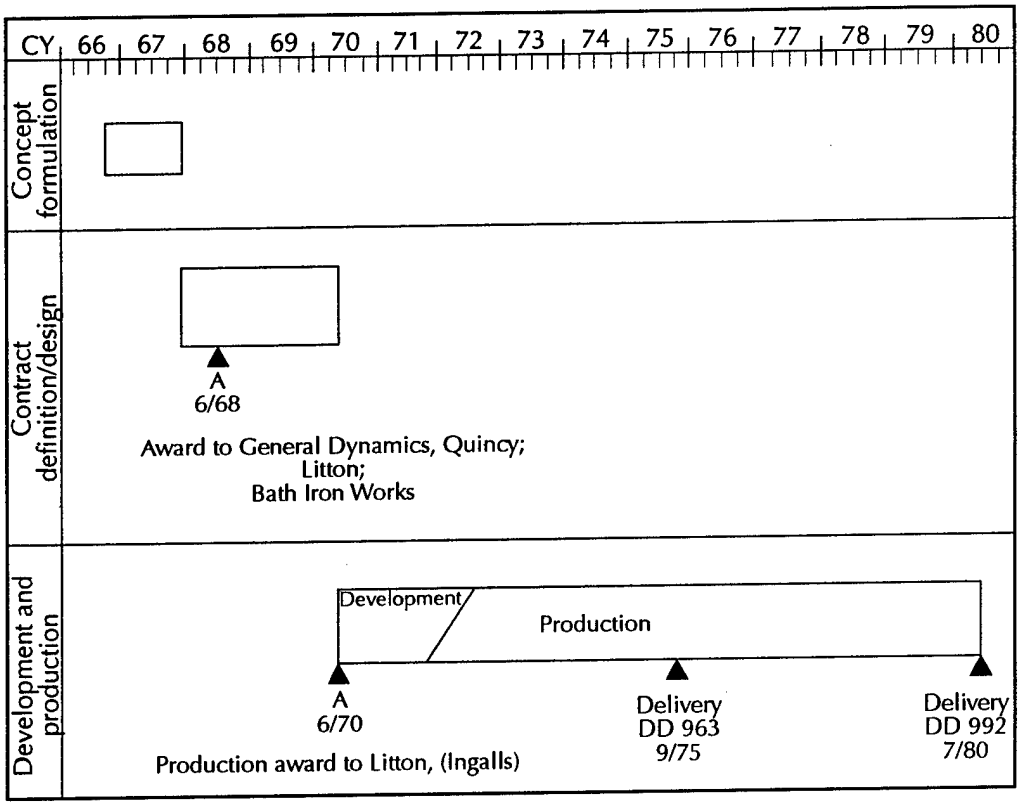
The process the Navy uses to develop a new class of combatants begins with a series of iterative conceptual studies that often take a year or more to complete. These studies define the threat projected for the initial[4] years of the ship's service life; postulate numerous mission alternatives and how ships of various capabilities would perform against those threats and missions; and suggest different combinations of weapon and ship characteristics and various force levels. The Navy then selects one or two of the proposed alternatives, distills the threat and mission results, narrows the list of possible weapon systems or capabilities, and transfers the resulting ship requirements to the Naval Sea Systems command for initial design work. At this point, there are usually some additional iterations that trade off selected operational requirements with cost, size, manning, or some other ship or program feature.

Next, members of the technical community in both industry and government define the tentative configuration in more detail and formulate an acquisition strategy that will lead, ultimately, to the award of a lead ship contract and start of construction. The award of a production ship contract follows soon thereafter. Overlaid on this process are the decision milestones of the Department of Defense Acquisition review and control process (DODD 5000.1), with specific Defense Acquisition Board decision-making requirements for key milestones of the development. Although the DD963 and the FFG7/ DDG51 classes were developed under different DOD guidelines (DODD 3200.9 and an early version of DODD 5000.1, respectively) [5], the general sequence of events for surface combatant development, as

4. It is usually assumed that, as threats evolve during a combatant's service life, the ship systems can be upgraded or replaced after 10 or 15 years to meet the unforeseen or underestimated threats that develop after the ships enter the fleet.

shown in figures 1, 2, and 3, has been the same for decades, ranging from 8 to 9 years from the start of conceptual design to delivery of the lead ships.

Figure 1. DD963 class acquisition program



Throughout the development process, advocates and opponents of certain ship configurations and missions promote their ideas through the internal decision-making process, Congress, and the press. The intensity of the lobbying increases as budgets become firm and contract awards approach. High-end designs are invariably assailed by budget-conscious or antidefense opponents as being too costly, excessively capable, tailored for the wrong threat, or simply not necessary. Low-end designs are subject to equally strident objections on the grounds that we're planning to build too many, or they are not capable enough, or, again, that they are simply not necessary. The high-end advocates oppose the low-end proposals because they fear there

will never be any more high-end ships or because, on an individual ship basis, the low-end ship cannot counter every threat it might meet. The low-end advocates oppose the high-end ships because they know that we can build only a few of them and, as a result, our worldwide naval presence will suffer. And contractors (and their Congressional delegations) oppose any configuration likely to favor equipment or systems built by their competitors. The process, by its very nature, leads to compromises of both designs. At the high end, advocates have been forced to cut back the capability either to be affordable (as when the early DDG51 class ships were originally designed and built without a helicopter hangar) and/or to gain the support of some low-end advocates. Similarly, at the low end, advocates have had to add additional, costly capability, as was the case when a second helicopter hangar was added to the FFG-7 class late in the conceptual design period.

Figure 2. The FFG-7 class acquisition program

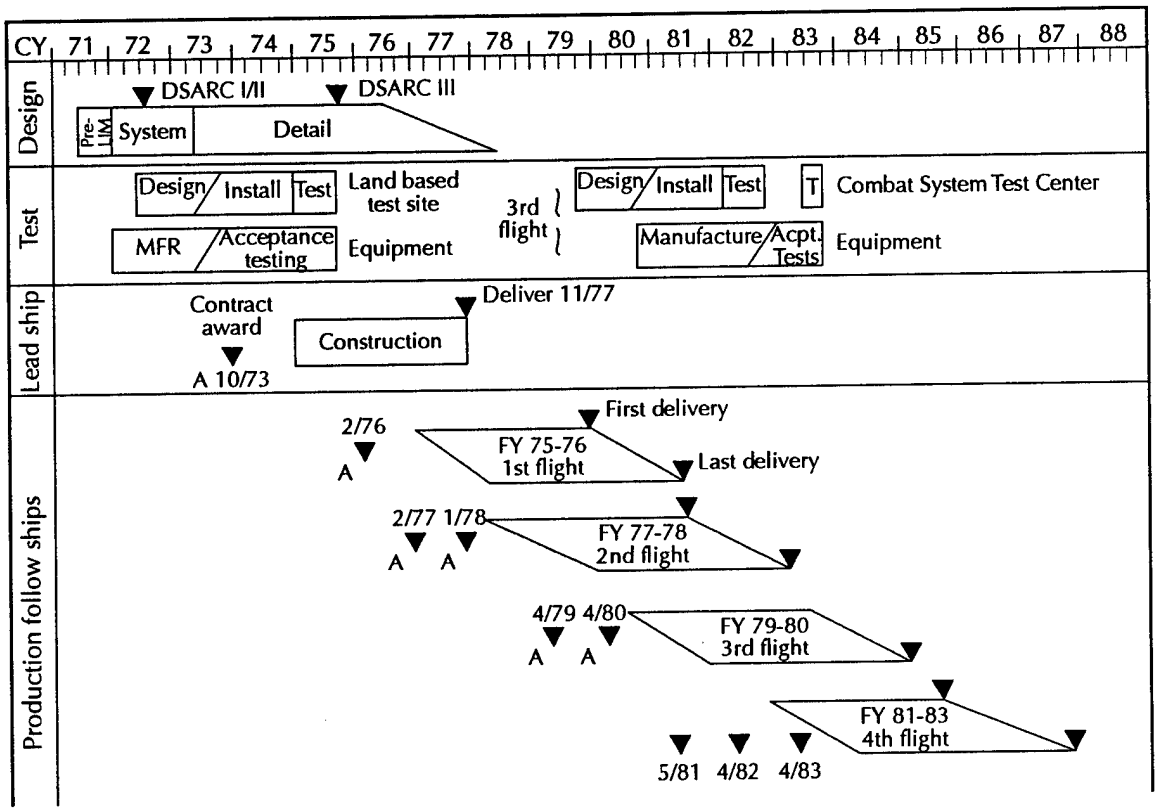
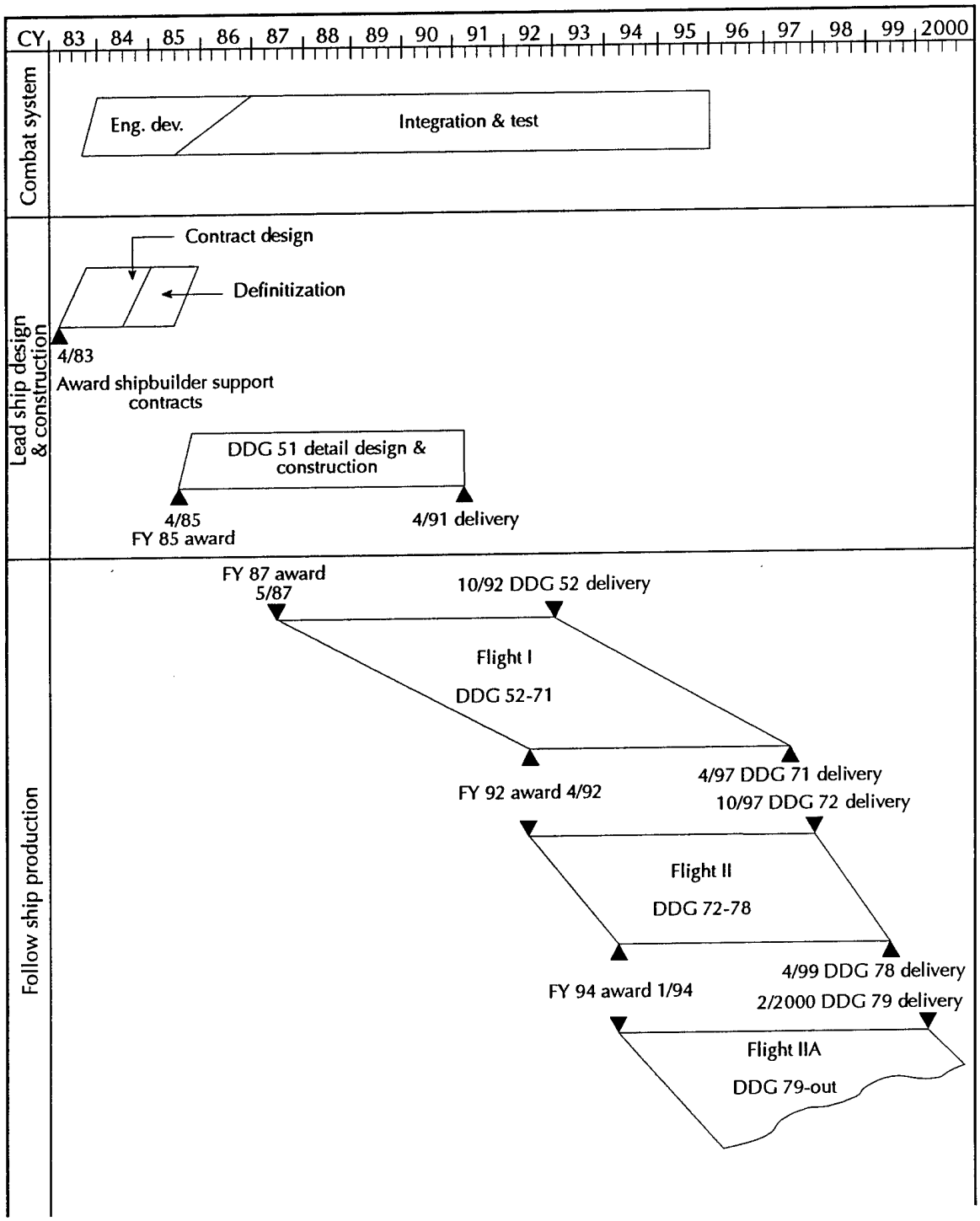


Figure 3. DDG-51 class acquisition program



The point is this: Because the Navy has always developed its fleet by introducing each new class of combatants as a single budgetary initiative, each class lives or dies not only on its technical or military merits and existing fleet balance, but also on where the lead ship of the class fits in the overall cycle of public opinion, management philosophy, and budget development, in the budget year it is introduced. A well laid-out plan might postulate some years of production of fully capable ships followed by production of a class of moderately capable ships, but what assurance do we have that the later years will turn out as planned? Was the last class that entered the fleet only a moderately capable ship? If so, most would say that it's time for a more capable ship, even if we can afford only a few. But is this year's budget year tighter than most, with competing demands not only from the domestic side but from other high-dollar programs in the Air Force, Army, or Marines? If so, the forced solution might be to build a marginally fully capable ship, or to build only one or two, or to build more moderately capable ships but with some upgrades. With these kinds of pressures influencing the selection of every new combatant's characteristics, it is not surprising that advocates of one philosophy or the other are unwilling to wait for introduction of the next new class to meet their requirements, and are prone to compromise in order to gain approval for anything close to what they believe is required now.

How should we proceed?

The way to end the divisive debate on the shape of future ship classes is to stop designing individual ship classes in successive years to meet pieces of the threat, or to fill gaps left by the previous ship classes introduced into the fleet. Rather, we should conceptualize the total spectrum of requirements that must be met, and then simultaneously design two[5] ship classes to be introduced in the same or successive budget years. Debate would still be required to arrive at mutually agreed-upon threat descriptions and total force-level requirements, but consensus should be easier to achieve because both high- and low-end advocates would have an equal chance of seeing their requirements satisfied in the same budget year. Such an approach would have these additional advantages:

- Standardization across the two classes of ships would be far greater than would otherwise be possible. Rather than try to achieve standardization by using, in a new class of ships, certain equipment that had been used in earlier classes (with the associated disadvantages of old technology, sole-source difficulties, and force-fitting new designs to accommodate the equipments), a simultaneous design of two classes would allow the Navy to use identical generators, pumps, controls, living space modules, propulsion equipment, etc., for both fully capable and moderately capable ships. The variations would be primarily in quantity (four generators versus three, four main engines versus two, etc.), rather than configuration. Even combat system equipment could be highly standardized, with, for example, primarily only

5. It may be that more than two ship classes would be the optimum solution for the allocation of surface combatant missions; for example, a fully capable, a moderately capable, and a limited capability ship design (destroyer, frigate, corvette; cruiser, frigate, patrol boat, etc., come to mind). As a practical matter, however, only two ship classes are advocated for any multiship design effort in order to ensure a manageable, affordable program.

signal processing and transmitter power varying between fully capable and moderately capable variants.

- Equipment costs would be lower for each ship because increased quantities of standard equipment would reduce average unit costs for design, manufacture, documentation, and spares.

- Ship design costs would be much less than would be the case if two designs were separated by several years. Ship design could be even more economical for the Navy if DOD and the Department of Transportation could agree that the requirements for the Coast Guard's next class of cutters—needed sometime between 2005 and 2010 [6]—would be similar enough to the Navy's moderately capable ship to allow the use of one design and one production run for both. In such a case, one design team would simultaneously develop two designs for three purposes, rather than three design teams doing three designs.

- Ship construction costs would be less for fully and moderately capable ships built within the same time frame, in constant dollars, than for the same quantity of like ships designed separately and procured separately over a period of years. This is a consequence of (a) standardization of components and modules across the classes providing economies of scale, and (b) reduced procurement actions (RFPs, proposals, evaluations, negotiations, etc.) in both government and industry.

- Ship designs would more likely be optimized rather than compromised solutions, thus reducing the total cost of meeting the threat. (Had the FFG-7 and DDG-51 classes been designed in the same time period, the frigates would probably have had only one helicopter hangar, but the early DDGs would have had a hangar as well.)

- There would be more flexibility in preparing shipbuilding budgets because (a) many ship type combinations could be accommodated in the budget for any given funding objective and (b) smaller quantities (one or two or even a gap year) of the fully capable ship in any given year would be less costly than if only the fully capable ship were being built. For example, as many as 42 full/moderate combinations exist for a surface combatant

shipbuilding program of, say, $2 billion to $2.6 billion[6] per year. (See figure 4.) This assumes moderately capable ship costs of between $400 million and $600 million, and fully capable costs of between $900 million and $1.1 billion (FY 1994 dollars).

- Perhaps most importantly, a multiship design and procurement program would serve to unite, rather than divide, the advocates for fully capable and moderately capable ship designs. The solution would be, simply, that defined missions would be allocated between the fully capable ship and the moderately capable ship; that one of each would be budgeted in a lead year or contiguous years; and that follow ships of each class would each be built in later years (after a gap of at least one year to provide ample time to prove out key subsystems of each design) according to an agreed ratio of ship types established during earlier conceptual studies, or in accordance with a modified ratio dictated by emerging threats.

Although larger than a conventional design team, the team that produces the SC21 multiship design would closely resemble the teams used for prior major class designs such as the FFG-7 and DDG-51. However, the emphasis must be different. Although standardization (the use of components and systems that are already in the Navy inventory) is considered in all tradeoff studies in a conventional design, significant standardization is seldom achieved across classes. In the past, new designs that require marinized gas-turbine main-propulsion engines have standardized on the LM2500 engines, but most other major systems and components have been tailored for each new class as it is designed. The usual result is that electrical, auxiliary, and hull systems differ from class to class. In these cases, standardization between designs was a consideration, but not a compelling one because other design priorities took precedence. For the SC21 multiship design effort, standardization of components and modules *must* be a driving consideration to reap the maximum savings in design, construction, and logistics.

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6. Assumes Navy Total Obligational Authority (TOA) of $67 billion (the approximate FY 1994 level), and assumes surface combatant funding levels of 3 percent to 4 percent of TOA (since 1962, surface combatant budgets have varied from 1 percent to 9 percent of TOA, and averaged 4 percent of TOA).

Figure 4. Annual construction costs for various combinations of surface combatants ($B)

Moderately capable unit cost	Fully cap. unit cost / Qty.	$900M each					$1B each					$1.1B each				
	Qty.	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
$400M each	0	0	.9	1.8	2.7	3.6	0	1.0	2.0	3.0	4.0	0	1.1	2.2	3.3	4.4
	1	.4	1.3	2.2	3.1	4.0	.4	1.4	2.4	3.4	4.4	.4	1.5	2.6	3.7	4.8
	2	.8	1.7	2.6	3.5	4.4	.8	1.8	2.8	3.8	4.8	.8	1.9	3.0	4.1	5.2
	3	1.2	2.1	3.0	3.9	4.8	1.2	2.2	3.2	4.2	5.2	1.2	2.3	3.4	4.5	5.6
	4	1.6	2.5	3.4	4.3	5.2	1.6	2.6	3.6	4.6	5.6	1.6	2.7	3.8	4.9	6.0
	5	2.0	2.9	3.8	4.7	5.6	2.0	3.0	4.0	5.0	6.0	2.0	3.1	4.2	5.3	6.4
	6	2.4	3.3	4.2	5.1	6.0	2.4	3.4	4.4	5.4	6.4	2.4	3.5	4.6	5.7	6.8
	7	2.8	3.7	4.6	5.5	6.4	2.8	3.8	4.8	5.8	6.8	2.8	3.9	5.0	6.1	7.2

Moderately capable unit cost	Fully cap. unit cost / Qty.	$900M each					$1B each					$1.1B each				
	Qty.	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
$500M each	0	0	.9	1.8	2.7	3.6	0	1.0	2.0	3.0	4.0	0	1.1	2.2	3.3	4.4
	1	.5	1.4	2.3	3.2	4.1	.5	1.5	2.5	3.5	4.5	.5	1.6	2.7	3.8	4.9
	2	1.0	1.9	2.8	3.7	4.6	1.0	2.0	3.0	4.0	5.0	1.0	2.1	3.2	4.3	5.4
	3	1.5	2.4	3.3	4.2	5.1	1.5	2.5	3.5	4.5	5.5	1.5	2.6	3.7	4.8	5.9
	4	2.0	2.9	3.8	4.7	5.6	2.0	3.0	4.0	5.0	6.0	2.0	3.1	4.2	5.3	6.4
	5	2.5	3.4	4.3	5.2	6.1	2.5	3.5	4.5	5.5	6.5	2.5	3.6	4.7	5.8	6.9
	6	3.0	3.9	4.8	5.7	6.6	3.0	4.0	5.0	6.0	7.0	3.0	4.1	5.2	6.3	7.4
	7	3.5	4.4	5.3	6.2	7.1	3.5	4.5	5.5	6.5	7.5	3.5	4.6	5.7	6.8	7.9

Moderately capable unit cost	Fully cap. unit cost / Qty.	$900M each					$1B each					$1.1B each				
	Qty.	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
$600M each	0	0	.9	1.8	2.7	3.6	0	1.0	2.0	3.0	4.0	0	1.1	2.2	3.3	4.4
	1	.6	1.5	2.4	3.3	4.2	.6	1.6	2.6	3.6	4.6	.6	1.7	2.8	3.9	5.0
	2	1.2	2.1	3.0	3.9	4.8	1.2	2.2	3.2	4.2	5.2	1.2	2.3	3.4	4.5	5.6
	3	1.8	2.7	3.6	4.5	5.4	1.8	2.8	3.8	4.8	5.8	1.8	2.9	4.0	5.1	6.2
	4	2.4	3.3	4.2	5.1	6.0	2.4	3.4	4.4	5.4	6.4	2.4	3.5	4.6	5.7	6.8
	5	3.0	3.9	4.8	5.7	6.6	3.0	4.0	5.0	6.0	7.0	3.0	4.1	5.2	6.3	7.4
	6	3.6	4.5	5.4	6.3	7.2	3.6	4.6	5.6	6.6	7.6	3.6	4.7	5.8	6.9	8.0
	7	4.2	5.1	6.0	6.9	7.8	4.2	5.2	6.2	7.2	8.2	4.2	5.3	6.4	7.5	8.6

Both designs should be held to a design-to-cost limit that overrides performance requirements. Although a design-to-average-unit-cost objective is a requirement of DODI 5000.2 for major (ACAT I) programs, only one Navy shipbuilding project, the FFG-7 class, has ever been managed with such a design-to-cost limit. This program was so successful at controlling cost increases [7] and in delivering ships on time, that it produced the largest class of ships built by a western-block Navy since World War II. However, despite this program's success, the Navy never returned to design-to-cost as a management technique for a total program. (The DDG-51 had design-to-cost constraints imposed after operational performance requirements were established [8], but this ruled out trading off combat capability for cost, which has the most potential for large savings—as demonstrated by the FFG-7 program). The compelling rationale for a design-to-cost *constraint* is stated in the Packard Commission Report:

> The affordability decision requires that a subjective judgement be made on how much a new military capability is worth. If a new weapon system can be developed and produced at that target cost, it may be authorized for development; otherwise, ways should be found to extend the life of the existing system. Determining a target cost is difficult, to be sure, but CEOs in industry must make comparably difficult decisions on which their companies' survival depends [9].

What are the disadvantages?

There are potential disadvantages to embarking on a multiship program to meet the SC21 mission:

- One major problem that might arise is that the full range of missions identified for the surface combatants may best be met by very different hull forms (for example, a SWATH moderately capable ship and a conventional fully capable ship, or vice-versa), with reduced benefits of standardization or economies of scale. In such a case, a multiship program would still retain the major advantage of united support, but the monetary benefits of parallel design and production would likely be lessened.
- A second potential problem is that a simultaneous effort could severely tax the Navy's design capability because the effort would likely require at least half again as many resources as would a typical lead-ship design task. However, greater reliance on industry for conceptual or system design work, or a combined industry-government design effort, would mitigate this problem and have the added benefit of ensuring a more producible design.
- The cost of an expanded design effort would be greater than that of a traditional design effort in the year it is conducted (but would cost less overall than two separate lead-ship designs conducted some years apart).
- Some might argue that the simultaneous introduction of two new surface combatants would result in fleet block obsolescence, but actually the average age of the fleet would not change under this approach. No fleet can have all new ships at any given time; it is always made up of a mix of new, old, and oldest. Traditionally, however, the fleet has aged by class because it was built one class at a time. The Knox-class frigates were recently retired, and retirements of DD963, FFG-7, CG-47,

and DDG-51 classes will follow roughly in the order in which they were introduced.[7] The result is a surface combatant fleet that is always relatively weak against one particular threat because there is always one ship class that was introduced to meet that threat category that happens to be the oldest class in the fleet. And so the class is modernized as a compromise solution, or a new class is developed that emphasizes defeating the latest threat, with defense against other threats de-emphasized for affordability purposes, and the cycle continues. This cycle of "threat response obsolescence" can only be broken by building solely multimission fully capable ships designed to meet the highest threats of all categories (an approach already discussed and rejected as being too costly) or by simultaneously introducing a mix of ship types as we propose here. Under this second scenario, the fleet will also age, but it will be better able to keep pace with the evolving threats of all categories because both the fully capable and the moderately capable ships in the fleet would be phased in over time and incremental improvements against the total threat could be made in each production year (as was done on the FFG-7 and DDG-51 class ships through "flight" changes inserted in later production years—see figures 2 and 3).

7. There will be exceptions, of course, depending on the threats existing at the time each class nears the end of its useful service life, and on other factors such as manning or high-maintenance requirements. (High-manning and/or maintenance-intensive ships may be more likely to be retired first.)

The principles applied to SC21

Our purpose in this paper is not to advocate specific SC21 missions or force-levels, or to suggest the configuration that various SC21 candidate ship types might take, because other authors have done well to stimulate thought in these areas already [10 through 15]. Rather, we propose the principles that should be applied to the formulation of SC21 requirements, design alternatives, and acquisition plans based on lessons learned from the Navy's ship definition process over the past three decades. These principles are as follows:

- Navy planners should strive to ensure that the fleet of the 21st century not only has fully capable ships to meet the most serious threats, but is also properly sized to maintain global presence and worldwide commitments.
- Navy force-level planners should recognize that low-end missions cannot be met over an extended period of time merely by using older fully capable ships because that would eventually result in a small fleet of large, high-maintenance ships that are inefficient to operate and poorly suited to the very low-end missions. Therefore, some moderately capable ships must be acquired through new construction, along with fully capable ships.
- SC21 conceptual planners should not limit the proposed solution to one ship class, but should consider an allocation of the total spectrum of surface combatant mission requirements across two ship classes, to be introduced simultaneously in an affordable mix. This would serve to solidify support from advocates of both ship types, reduce the incidents of design compromise, eliminate block obsolescence of a single threat-specific class, increase standardization throughout the Navy, and lower design and production costs of both types—especially the fully capable variant which would otherwise only be built in small quantities.

- Design of the ships required to meet the surface combatant missions of the next century should be conducted simultaneously by one collocated Navy-industry[8] design team. To reduce design, construction, and test costs, the team should emphasize commonality of modules, systems, and equipment.

- As mission requirements are allocated across the ship designs, and we become confident in the accuracy of our cost estimates, firm design-to-cost limits should be established to ensure that adherence to cost limits for both ship types is at least as essential as adherence to other performance requirements.

- Figure 5 summarizes annual production possibilities for three different combinations, constrained to $2.0 billion to $2.6 billion per year: a lowest cost alternative, made up of relatively austere surface combatant designs ($400 million and $900 million, respectively); a moderate cost alternative ($500 million and $1 billion, respectively); and a most-capable alternative ($600 million and $1.1 billion, respectively). Using these annual production possibilities, three notional production programs,[9] yielding 24, 21, or 18 surface combatants,[10] are postulated in figure 6. Of course, many more combinations exist as costs decrease for the moderately capable ship, or as total budget levels increase, thus increasing the probability that an affordable program for building multiple surface

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8. If Coast Guard requirements are also to be met by one of the ship types, the design team should include Coast Guard representation.

9. To reduce risk, each notional plan provides a one-year gap between the lead ship and the first production ship, building to a relatively constant production rate; and each plan assumes that production of the moderately capable ships should lead production of the fully capable ships in schedule and quantity because production of the fully capable DDG-51 class is just ending as the SC21 Program begins. This approach results in delay of the first fully capable production ship until the *fifth* year of the moderately capable program, which will reduce the fully capable ship production costs due to commonality with equipment and systems already in production.

10. Actual required quantities must await completion of SC21 force-level and COEA studies.

combatants could be structured for almost any fleet sizing objective, even with marginal budgets.

Figure 5. Possible combinations for annual SC21 shipbuilding costs of $2 billion–$2.6 billion

Lowest-cost combination

Moderately capable @ $400M ea. qty./yr.	6	5	4	3	2	1
Fully capable @ $900M ea. qty./yr.	0	0	1	1	2	2
Annual cost	$2.4B	$2B	$2.5B	$2.1B	$2.6B	$2.2B

Moderate cost combination

Moderately capable @ $500M ea. qty./yr.	5	4	3	2	1	0
Fully capable @ $1B ea. qty./yr.	0	0	1	1	2	2
Annual cost	$2.5B	$2B	$2.5B	$2B	$2.5B	$2B

Highest-cost combination

Moderately capable @ $600M ea. qty./yr.	4	2	0
Fully capable @ $1.1B ea. qty./yr.	0	1	2
Annual cost	$2.4B	$2.3B	$2.2B

Figure 6. Notional SC21 production programs

Lowest-cost/ship

Program year	1	2	3	4	5	6	7	Total
Qty. @ $400M each	1[1]	0	4	5	4	3	2	19
Qty. @ $900M each	2[2]	2[2]	1[1]	0	1	1	2	5[3]
Total annual cost ($B)	.4[1][3]	0[3]	2.5[1]	2.0	2.5	2.1	2.6	$12.1B[1][3]
								Ave= $504M/ship[1][3]

Moderate-cost/ship

Program year	1	2	3	4	5	6	7	Total
Qty. @ $500M each	1[1]	0	3	4	3	4	3	18
Qty. @ $1B each	2[2]	2[2]	1[1]	0	1	0	1	3[3]
Total annual cost ($B)	.5[1][3]	0[3]	2.5[1]	2.0	2.5	2.0	2.5	$12B[1][3]
								Ave= $571M/ship[1][3]

Highest-cost/ship

Program year	1	2	3	4	5	6	7	Total
Qty. @ $600M each	1[1]	0	2	4	2	4	2	15
Qty. @ $1.1B each	2[2]	2[2]	1[1]	0	1	0	1	3[3]
Total annual cost ($B)	.6[1]	0[3]	2.3[1]	2.4	2.3	2.4	2.3	$12.3B[1][3]
								Ave= $683M/ship[1][3]

Notes: (1) Excludes lead-ship design, and production start-up costs

(2) Last DDG-51 class ships

(3) Excludes DDG-51

(4) All costs exclude annual increase due to inflation

(5) All costs exclude annual decrease due to learning

Conclusion

The SC21 is to be developed for production during a period when procurement budgets are expected to be much smaller than at any time in the last half-century, and yet the Navy's mission is likely to continue to require large numbers of surface combatants—many of which must be able to counter state-of-the-art high-level threats.

The only solution is to acknowledge that no one ship type could meet all requirements, and to develop a plan that provides for the economic design and production of a surface combatant "system" for the 21st century. This system would include a mix of some fully capable ships and some moderately capable ships. For such a plan to succeed, design and subsequent production of both ship types should proceed concurrently. This should avoid expensive compromises in performance or quantity, as well as block obsolescence of one type or the other. Rather than increase costs, concurrent design of both ships (i.e., the SC21 "system") would save design costs overall, and permit more standardization than has previously been possible across ship classes. Similarly, concurrent production of two ship types is not a costly luxury; rather, it is likely to be *the only feasible way to build small quantities of fully capable ships economically*—assuming, of course, a high degree of commonality with the moderate capability ships. Therefore, standardization is envisioned not only as a desirable by-product of the concurrent design process, but also as a key element of the program, to ensure the lowest possible costs of production.

Finally, because cost growth in a multiship program could adversely affect quantity and performance of two ship classes concurrently, *both ship types should be developed with firm design-to-cost constraints that, once established and approved, are not subordinated to performance requirements.*

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